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## 1. Your reference

6/LC/11856

## 2. Patent application number

*(The Patent Office will fill in this part)***9922678.9**3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Wivenhoe Technology Limited  
 University of Essex  
 Wivenhoe Park  
 Colchester  
Essex CO4 3SQ

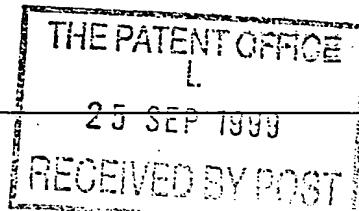
Patents ADP number *(if you know it)* 06247084001.

If the applicant is a corporate body, give the country/state of its incorporation

United Kingdom

## 4. Title of the invention

Optical Data Signals

5. Name of your agent *(if you have one)*

Sanderson &amp; Co.

GILL JENNINGS &amp; EVERY

*"Address for service" in the United Kingdom to which all correspondence should be sent (including postcode)*

34 East Stockwell Street  
 Colchester  
Essex  
 CO1 1ST

BROADGATE HOUSE  
 7 ELTON STREET  
 LONDON  
 EC2M 7LH

Patents ADP number *(if you know it)*

1446001

745002.

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Country

Priority application number  
*(if you know it)*Date of filing  
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## 7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

Date of filing  
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11.

I/We request the grant of a patent on the basis of this application.

Sanderson & Co.  
Agents for the applicant

Signature

Date 24.9.1999

12. Name and daytime telephone number of person to contact in the United Kingdom

Francis C. Gillam 01206 571187

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## OPTICAL DATA SIGNALS

This invention relates to a method of encoding control information on an optical data signal, to a transmitter configured to encode such information, and to a method of modifying or removing control information carried by an optical data signal.

In an all-optical packet-switched network, the signal remains in the optical domain from source to destination. In these networks, wavelength converters will be an enabling technology for dynamic routing of optical packets through the network and for resolving contention within the switching nodes.

10 The routing control is a critical function; the packets of data have a routing tag or header and the ability dynamically to update or modify the routing tag/header is essential in certain types of network architectures. This functionality must be performed with minimal impact on the optical payload and several techniques for achieving this have been previously proposed.

15 The present invention aims at providing a particularly effective technique permitting the modification of control tags or headers associated with packets transmitted through an optical network, which technique has a minimal effect on the data itself.

According to one aspect of this invention, there is provided a method of  
20 encoding control information on an optical data signal to be transmitted through an optical network, comprising operating an optical source to generate a substantially coherent continuous-wave light beam, amplitude-modulating the light-beam with a data-stream-to-produce-an-optical-data-signal,-and-also

modulating the data signal with control information, using a substantially constant amplitude modulation technique.

According to a second aspect of this invention, there is provided an optical data signal transmitter adapted to encode control information on an optical data signal to be transmitted through an optical network, which transmitter comprises an optical source arranged to generate a substantially coherent continuous-wave light beam, an amplitude-modulator which modulates said light beam with a data stream to produce an optical data signal, and a substantially constant amplitude modulator arranged also to modulate the data signal with control information, using a non-amplitude modulation technique.

A third aspect of this invention provides a method of modifying control information carried by an optical data signal transmitted through an optical network, comprising the steps of encoding the control information on the optical signal in a non-amplitude varying format so as to be associated with a stream of data, transmitting the optical signal to a traffic processor, reading and decoding the control information and then deciding upon the routing of the stream of data depending upon the decoded information, and passing the optical data signal through a wavelength converter based on a semiconductor optical amplifier thereby simultaneously removing the control information.

It will be appreciated that the present invention relies on the fact that only intensity-modulated (IM) signals are wavelength-converted when employing cross-gain modulation (XGM) in a semi-conductor optical amplifier (SOA). An SOA is therefore opaque to modulation formats that convey information in a non amplitude-varying fashion. A preferred form of the method of this invention

employs a subcarrier signalling format and encodes this information on the polarisation of the continuous-wave light preceding the payload of an optical packet. The header information is extracted using direct-detection and the original header is removed without any additional guard bands or timing control.

5

By way of example only, further details of methods of and apparatus for performing this invention will now be described, referring to the accompanying drawings, in which:-

Figure 1 illustrates an example of an optical packet transmitter;  
10 Figure 2 illustrates a technique for control information decoding and removal;

Figure 3a shows the header information at the input to the polarisation modulator and Figures 3b and 3c the output of decoder in a switching node;

Figure 4 shows the optical spectral output after the AWG; and  
15 Figure 5 shows the AWG output after wavelength conversion

Referring initially to Figure 1, a data packet is 1.6 $\mu$ s in duration and consists of a payload containing a pseudo-random bit sequence (PRBS) at 2.5Gbit/s, an 8-bit header and a conservative guard band of 20ns. The latter allows for the laser turn-on/turn-off times associated with the wavelength converter within the node. The header consists of a byte of 78Mbit/s non-return-to-zero (NRZ) data: start and stop bits for synchronisation and six data bits that denote the packet destination. The baseband header amplitude modulates a 2.7GHz subcarrier in the microwave mixer. A 5Gbit/s LiNbO<sub>3</sub> phase modulator was used for modulating polarisation states. The linearly

polarised signal from the Mach-Zehnder interferometer (amplitude modulator) was rotated to be 45° to the principal axis of the phase modulator, and the drive voltage adjusted such that orthogonal polarisation states were assigned for a peak and trough of the subcarrier cosine. An erbium-doped fibre amplifier (EDFA) amplifies the resulting signal.

At the switching node (Figure 2), the optical signal is filtered by the de-multiplexer ( $\lambda_{3dB} = 1.8\text{nm}$ ) and the tap coupler directs 10% of the signal to three polarisers via an optical splitter. (This may be implemented using a Stokes Analyser). The polarisers are arranged to pass horizontally polarised light through one arm, polarisation states at +45° to the vertical through a second arm, and right hand circular through the third arm. In this way, the incoming polarisation-modulated subcarrier will always result in an amplitude-varying component at 2.7GHz at the output when a "one" is received for all evolutionary states of the signal. After optical to electrical conversion (O/E), each of the signals are band-pass filtered ( $f_c = 2.7\text{GHz}$ ,  $f_{3dB} = 120\text{MHz}$ ), rectified using a microwave mixer and filtered using a low-pass filter ( $f_{3dB} = 50\text{MHz}$ ). The sum of the components is the recovered header.

The control electronics process the baseband header information to determine the wavelength to which the payload is to be converted. After passing through an optical delay equal to the electronic processing time (50ns), the signal is coupled into the wavelength converter using an optical circulator. Cross-gain-modulation in a SOA is used to translate the wavelength of the packet to 1552nm. To obviate the need for an output filter, a counter-propagating arrangement is employed, and the input/output wavelengths are

chosen to lie in the stop-and pass-bands of the arrayed-waveguide grating (AWG). In this way, very high rejection of the residual input signal, due to the SOA residual facet reflectivity, is achieved.

To demonstrate the principle of operation, alternate packets may be  
5 encoded with a "10101001" header. Within the switching node, a lookup table  
is updated at the start of the process to direct such packets to output port 1 of  
the AWG by activating the 1552nm laser at the appropriate time. Figure 3a  
shows the header signal at the input to the polarisation modulator after up-  
conversion in the microwave mixer. The output of the optical packet generator  
10 is fed directly into the optical switching node arrangement. The polarisation  
controller at the input of the header receiver allows the state of polarisation of  
the signal to be adjusted in order to present a variety of polarisation states to  
the receiver.

The decoded signal at the output of the electrical combiner in the  
15 switching node is shown in Figure 3b. To observe the effects of pattern  
dependence, a  $2^{23} - 1$  PRBS sequence was transmitted and the resulting data  
eye is shown in Figure 3c.

Figure 4 shows the routed packets at output port 1 of the AWG after  
wavelength conversion. The residual input signal at 1554.4nm is suppressed to  
20 more than 45dB less than the converted signal, and the time-domain plots are  
illustrated in Figure 5. Owing to the inverting nature of the SOA, the header is  
extinguished and no polarisation to amplitude conversion is visible (lower  
trace).

Confirmation of suppression of the header can be obtained by feeding the output of the wavelength converter to a header decoder; tests have shown that no residual header could be observed.

By increasing the bandwidth of the band-pass filter, the header can be 5 transmitted at a higher bit-rate. Alternatively, the header data aggregate can be increased by employing frequency division multiplexing of additional subcarrier signals.

For optical packet-switched networks where polarisation scrambling is required for the high bit-rate payloads, and the described technique of this 10 invention may easily be implemented. In this scenario the depolarising tone, driving the scrambler, may be modulated with the inverse of the header information to impose the header information on to the optical packet.

15 From the above, it can be seen that the invention provides a technique for polarisation-encoding subcarrier-multiplexed headers on to an optical packet. The XGM functionality of an SOA is used effectively to remove the header without the addition of any timing control, and without the need for a guard band between the header and payload. A simple direct-detection receiver can be 20 used to decode the header information and all-optical wavelength conversion and routing of 2.5Gbit/s payloads is thereby possible.

## CLAIMS

1. A method of encoding control information on an optical data signal to be transmitted through an optical network, comprising operating an optical source to generate a substantially coherent continuous-wave light beam, amplitude-modulating the light beam with a data stream to produce an optical data signal, and also modulating the data signal with control information, using a substantially constant amplitude modulation technique.
2. A method as claimed in claim 1, wherein the control information is added to the optical data signal by means of a polarisation modulation technique.
- 10 3. A method as claimed in claim 1, wherein the control information is added to the optical data signal by means of a phase-shift-keying modulation technique.
4. A method as claimed in claim 1, wherein the control information is added to the optical data signal by means of a frequency-shift-keying modulation technique.
- 15 5. A method as claimed in claim 4, wherein the substantially constant amplitude modulation technique is applied to the optical beam before the modulation thereof with the data stream.
6. A method as claimed in claim 5, wherein the substantially constant amplitude modulation technique is applied directly to the optical source.
- 20 7. A method as claimed in any of claims 1 to 4, wherein following the modulation of the light beam with the data stream, the optical data signal is passed a constant amplitude modulator to which is supplied the control information to be applied to the optical data signal.

8. A method as claimed in any of the preceding claims, wherein the data stream is applied to the light by means of a Mach-Zehnder interferometer to which is supplied the data stream, so as to produce an amplitude-modulated optical data signal.

5 9. A method of encoding control information on an optical data signal to be transmitted through an optical network as claimed in claim 1 and substantially as hereinbefore described, with reference to the accompanying drawings.

10. An optical data signal transmitter adapted to encode control information on an optical data signal to be transmitted through an optical network, which 10 transmitter comprises an optical source arranged to generate a substantially coherent continuous-wave light beam, an amplitude-modulator which modulates said light beam with a data stream to produce an optical data signal, and a substantially constant amplitude modulator arranged also to modulate the data signal with control information, using a non-amplitude modulation 15 technique.

11. An optical data signal transmitter as claimed in claim 10, wherein the optical source comprises a laser source.

12. A method of modifying control information carried by an optical data signal transmitted through an optical network, comprising the steps of encoding 20 the control information on the optical signal in a non-amplitude varying format so as to be associated with a stream of data, transmitting the optical signal to a traffic processor, reading and decoding the control information and then deciding upon the routing of the stream of data depending upon the decoded information, and passing the optical data signal through a wavelength converter

based on a semiconductor optical amplifier thereby simultaneously removing the control information.

13. A method as claimed in claim 12, wherein further control information is encoded on the optical signal following wavelength conversion thereof, so as to 5 be associated with the wavelength-converted data signal.

14. A method as claimed in claim 13, wherein the further control information is encoded on the optical signal by a substantially constant amplitude modulation technique.

15. A method as claimed in claim 14, wherein the further control information 10 is added to the wavelength-converted optical data signal by means of a polarisation modulation technique.

16. A method as claimed in claim 12, wherein the further control information is added to the wavelength-converted optical data signal by means of a phase-shift-keying modulation technique.

15 17. A method as claimed in claim 12, wherein the further control information is added to the wavelength-converted optical data signal by means of a frequency-shift-keying modulation technique.

18. A method as claimed in any of claims 12 to 17, wherein the optical data signal comprises time-division multiplexed data packets each of which has 20 associated therewith individual control information.

19. A method as claimed in any of claims 12 to 18, wherein the optical data signal are carried by wavelength division multiplexed optical channels each of which has associated therewith individual control information.

20. A method as claimed in claim 18, wherein the control information 25 comprises a data header or tag for the data stream contained in each packet.

21. A method of modifying control information carried by an optical data signal transmitted through an optical wavelength-multiplexed network as claimed in claim 12 and substantially as hereinbefore described, with reference to the accompanying drawings.

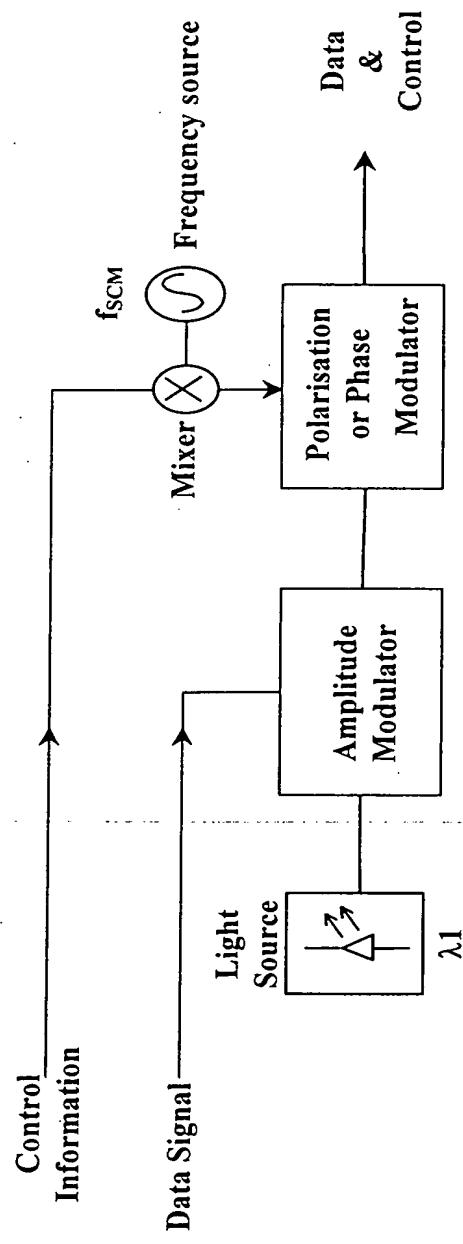
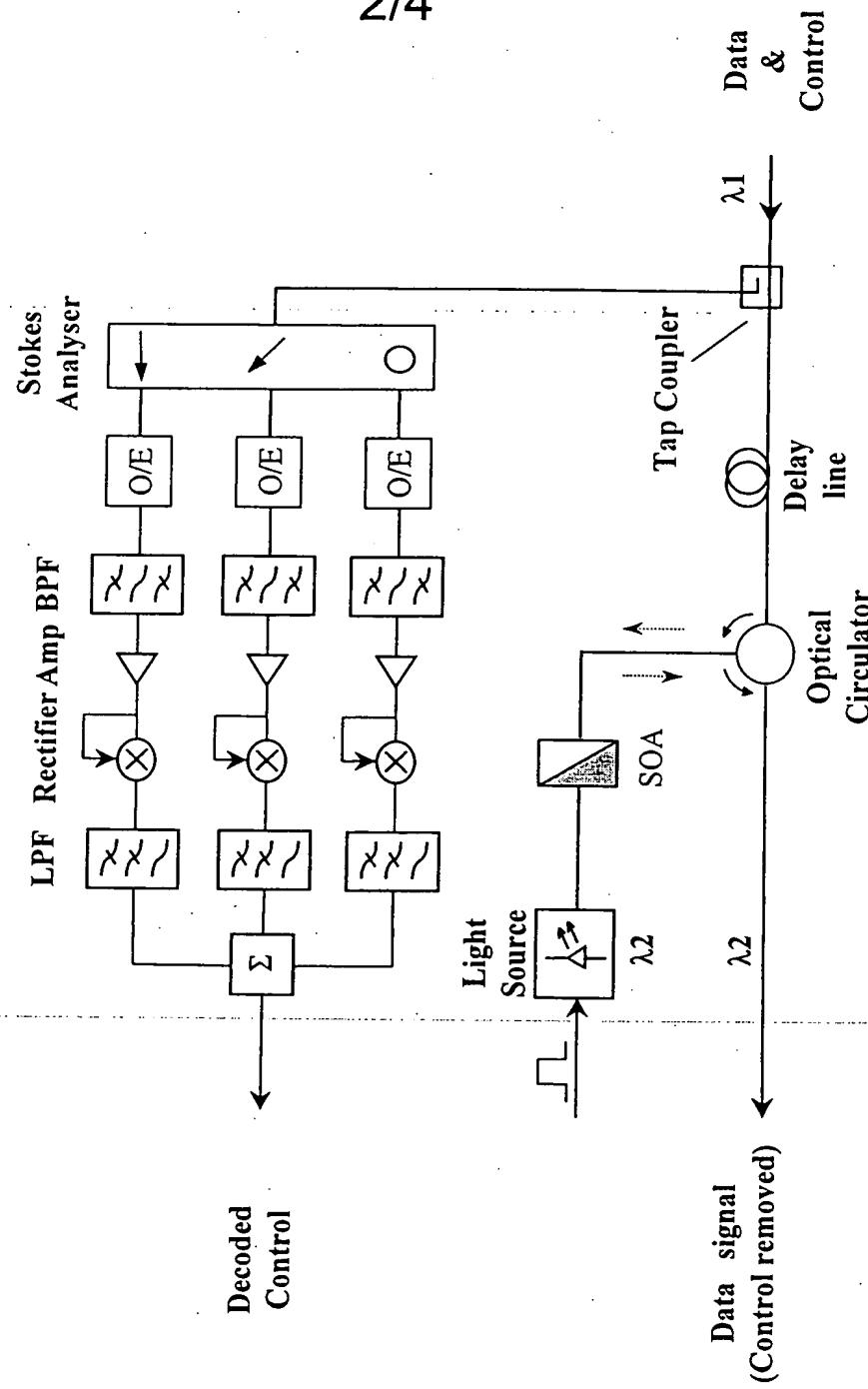


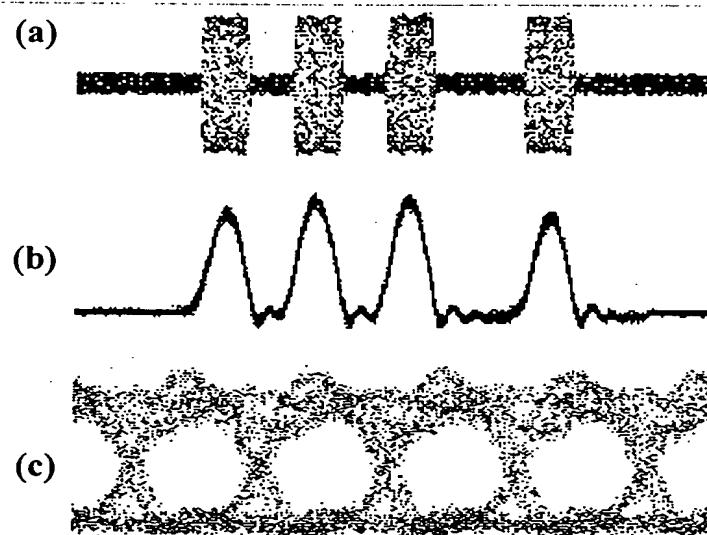
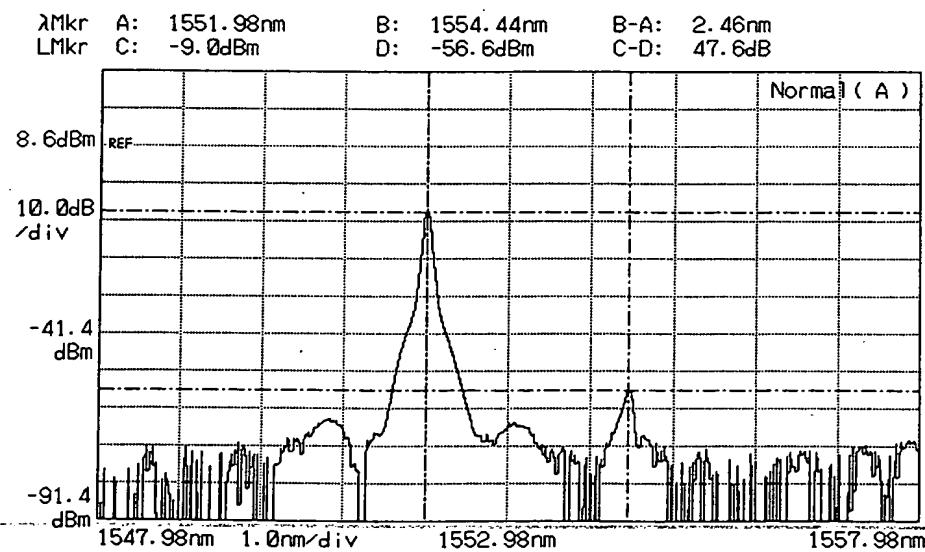
Figure 1

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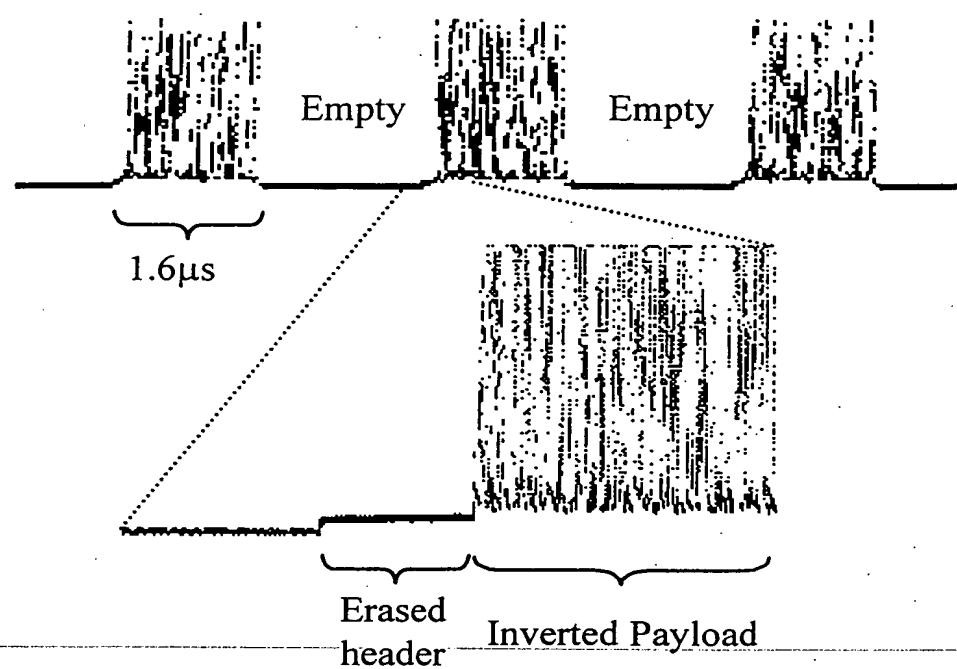
**Figure 2**

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**Figure 3****Figure 4**

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**Figure 5**



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